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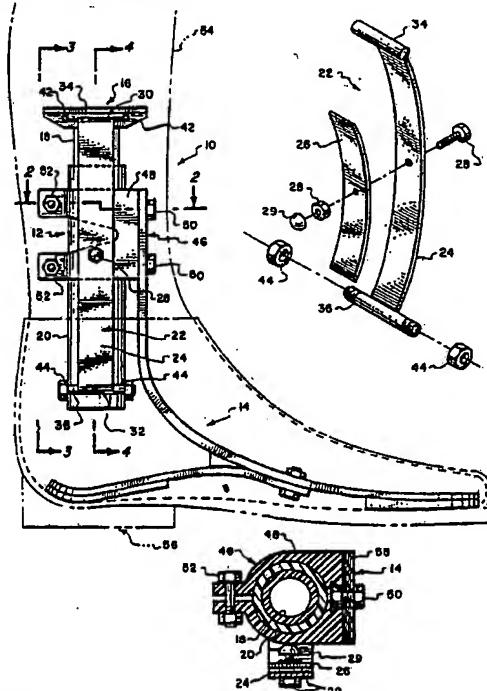
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(54) Title: ENERGY-STORING PROSTHETIC LEG PYLON



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ENERGY-STORING PROSTHETIC LEG PYLONBackground of the Invention:

This invention relates to leg prostheses in general, and specifically to a pylon which is capable of storing and subsequently releasing energy during use of the prosthesis. The pylon of the invention is characterized by a lightweight construction, and preferably may be modified and adjusted to accommodate an individual wearer's needs and particular uses.

Moreover, the pylon of the invention may be utilized in connection with any of a broad selection of prosthetic sockets for attachment to the wearer, as well as in connection with any of a broad selection of prosthetic feet attached to, or integrally formed with, the lower end of the pylon.

Various types of foot and leg prosthetic devices are known in the prior art. Such devices generally include some form of attachment for coupling the device to the dorsal end of the limb and for extending to the ground to provide body support. Moreover, these devices generally constitute attempts to simulate the structure and/or the performance of the human leg and foot.

Among the features desirable in leg and foot prostheses is the incorporation of some means for storing and releasing energy during use of the prosthesis; for example, during ambulation. Such energy performance permits the 5 wearer to expend less energy and to participate in activities not otherwise feasible to the wearer. Consequently, the wearer becomes less tired, is able to perform for longer periods of time. In many ways, energy-storing and releasing prostheses remove barriers and limitations which might otherwise restrict the wearer's activities. Examples of prostheses which provide energy storage and release are set forth in United States Letters Patent No. 4,547,913 for my 10 invention relating to a "Composite Prosthetic Foot and Leg", United States Letters Patent No. 4,822,363 for my invention 15 relating to a "Modular Composite Prosthetic Foot and Leg", and United States Letters Patent No. 5,037,444 for my invention relating to a "Prosthetic Foot".

Although the benefits and desirability of energy storage and release in prosthetic devices is known, no prior 20 art prosthetic devices provide those benefits in the relatively simple construction set forth in my present invention, which is adaptable to wide variety of applications, is readily manufacturable and adjustable, and permits an extremely sensitive energy performance.

In addition, and as indicated above, my present invention is compatible with a wide range of prosthetic feet and legs and enhances the performance of such devices.

Examples of such prosthetic foot devices include U.S. Pat.

5 No. 2,075,583 to Lange, which incorporates a rubber form mounted in operative relationship with a rigid metallic core, and No. 4,645,509 to Poggi, which teaches a prosthetic foot incorporating a monolithic keel or beam of relatively massive proportions intended to react to the load of an
10 amputee's body during walking, running, jumping, and the like and to release the resultant stored energy to create foot lift and thrust complementing the amputee's natural stride.

Some of the benefits of my inventions disclosed in
15 my aforementioned patents inhere in the interchangeable, lightweight construction which provides selectable degrees of strength and flexibility in a given structure. My present invention preferably permits similar interchangeability, providing additional or alternative control and
20 adjustability of the performance of the prosthesis. Moreover, my present invention provides some degree of those adjustability and performance benefits to wearers of otherwise conventional or non-energy-storing prosthetic devices.

Objects and Advantages of the Invention:

It is, therefore, an object of my invention to provide an energy-storing prosthetic pylon which may be incorporated in a prosthetic leg. The pylon preferably includes upper and lower pylon members connected by energy-storing means such as one or more elongated spring elements. The pylon members are preferably overlappingly interengaged and reciprocable one on the other. This interengagement of the upper and lower pylon members may be accomplished, for example, through the provision of an interfitting, slidably disposed sleeve and arm configuration for the pylon members. In the preferred embodiment, forces imposed on the pylon cause the aforesaid reciprocation of the pylon members and the corresponding storage of energy in the spring element or elements.

Among other things, the interengagement of the upper and lower pylon members assists in maintaining appropriate alignment of the pylon during use. Notably, such alignment may include one or more dynamic components; for example, in addition to the energy-storing compression which is one of the primary functions of the pylon, the alignment of the pylon members may permit rotation of "toe-in" and/or "toe-out" during use, such as is accomplished by known prosthetic "rotators". In other words, during use by the

wearer, the preferred embodiment of the invention permits a desired and determinable amount of rotation of the lower end of the pylon with respect to the wearer's socket. Such rotation is beneficial, and simulates the action of a natural human knee/ankle, in a number of activities that involve the twisting of a person's body with respect to their planted foot, such as golf, tennis, and the like.

The pylon is characterized by an upper extremity adaptable for securement to the wearer's limb and a lower extremity adaptable for securement to a prosthetic foot, with the aforesaid energy-storing means such as one or more elongated spring elements interconnecting or acting between the two extremities. In the preferred embodiment, the specific interconnection of the spring elements to the pylon extremities is preferably of a pivoting nature. Such a pivoting structure eliminates or greatly reduces the stress concentrations that would otherwise be present during compression of the pylon and spring elements. Non-pivoting interconnection of the spring to the pylon members could, of course, be utilized without departing from the teachings of the invention. When such pivoting structures are utilized, however, it is preferable to minimize the friction inherent in such a pivot. Any friction which occurs in the pivoting action results in a loss energy which could otherwise be

stored in the energy storage means and subsequently released beneficially to the amputee. A preferred method of minimizing this friction loss is to coat contacting surfaces with teflon or similar material, as discussed herein.

5 The particular selections of a device for attachment to the wearer and of a prosthetic foot may be permanently or demountably associated with the pylon. Demountable association permits one or more of the socket, the pylon, and/or the leg and foot prostheses components to be 10 readily exchanged with correspondingly constructed elements to provide size adjustment and/or different energy-performance characteristics to suit the size of leg and foot of the amputee or the stride, height, weight, and activity level of the amputee. Therefore, a range of combinations of 15 spring rate and size can be provided to the amputee. Moreover, manufacture and inventory costs are reduced because prostheses appropriate for amputees of greatly differing heights and weights can be assembled from a relatively small inventory of "standard" sized components.

20 Another object of the invention is the provision of a prosthetic pylon of the aforementioned character in which the energy-storing means such as one or more spring elements is fabricated from laminates, chopped fiber and/or other material maintained in operative relationship by an

encapsulating polymer such as a thermosetting or thermoplastic resin.

A further object of the invention is the provision of a prosthetic pylon of the aforementioned character which 5 includes upper and lower interengagable, relatively reciprocatable pylon members and energy storage means connected or operably disposed therebetween to maintain said lower member in an extended position relative to said upper member, whereby when a contact-generated compressive force is 10 impressed upon the lower member, it will be reciprocated relatively to said upper member to compress the energy storage means into an energy storage mode, and when said force is released the storage means will urge the lower member to its extended position.

15 Another object of the invention is the provision of the aforesaid prosthetic pylon, in which a multiplicity of said spring elements may be utilized in combination with each other to vary the resistance of the prosthesis to loads imposed thereupon. The concept of the multiplicity of 20 spring elements includes the provision of spring elements characterized by different spring rates, which permits the resistance of the total combination to deflection to be precisely adjusted to the weight, activity level and other

characteristics of the individual for whom said pylon is being adjusted.

Still another object of my invention is the provision of a prosthesis of the aforementioned character in which the energy storage and release means includes one or more members fabricated from rubber or a rubber-like material. Such rubber spring members may be utilized in connection with or instead of the aforementioned elongated spring elements.

Yet another object of my invention is the provision of a prosthesis of the aforementioned character having elongated spring elements and further including constraining means such as, for example, an elastic cord for constraining the amount of deflection of the one or more elongated spring elements. Such constraining means provide an additional means to "fine-tune" the energy performance of the prosthesis.

In order to impart a cosmetic aspect to the prosthetic leg, after proper fitting of the leg to insure that it is properly balanced and of appropriate size, the prosthesis may be encapsulated in a suitably shaped cosmetic shroud. The shroud must be sufficiently flexible so as not to inhibit the free movement and flexure of the leg, but, because of the inherently resilient and stress-absorbing

characteristics of said leg, little or no dependence is needed upon the ancillary cushioning action of the shroud. Moreover, the shroud should accommodate any desired flexure of the energy-storage means without incurring damage or 5 undesirably restricting such flexure.

Consequently, prosthetists and wearers will be able to adjust the flexibility of the pylon at their discretion. Through the provision of preferably demountable, adjustable attachment means such as gripping clamps for 10 attaching the prosthetic foot to the pylon, the pylon of my invention may be provided in standard lengths but still be readily "custom-fitted" to a wide range of effective lengths.

Other objects and advantages of the invention will 15 be apparent from the following specification and the accompanying drawings, which are for the purpose of illustration only.

Brief Description of the Drawings:

FIG. 1 is a side elevation view of a preferred 20 embodiment of a prosthesis constructed and assembled in accordance with the teachings of the invention;

FIG. 2 is a sectional view, taken along line 2-2 of FIG. 1;

FIG. 3 is a partial rear elevation view, taken along line 3-3 of FIG. 1;

FIG. 4 is a partially sectional rear view, taken along line 4-4 of FIG. 1;

5 FIG. 5 is an exploded view of a preferred embodiment of spring elements utilizable in the invention;

10 FIG. 6 is a side elevation view of an alternative embodiment of the invention, illustrating the disposition of the lower pylon member internally of the upper pylon member, and further illustrating the use of constraining means in connection with the elongated spring element;

FIGS. 7 and 8 are side elevation views illustrating alternative embodiments of the elongated spring element;

15 FIG. 9 is a side elevation view of another alternative embodiment of the invention, in which the energy storage means is disposed internally of the upper and lower pylon members;

FIG. 10 is a sectional view, taken along line 10-10 of FIG. 9;

20 FIG. 11 is a side elevation view of another alternative embodiment of the invention, in which the upper and lower pylon members have a non-circular cross-section;

FIG. 12 is a sectional view, taken along line 12-12 of FIG. 11;

FIG. 13 is a side elevation view of another alternative embodiment of the invention, illustrating an alternative means for attaching the lower prosthetic foot to the energy-storing pylon;

5 FIG. 14 is a sectional view, taken along line 14-14 of FIG. 13;

FIG. 15 is a side elevation view of another alternative embodiment of the invention;

10 FIG. 16 is a sectional view, taken along line 16-16 of FIG. 15;

FIG. 17 is a partially sectional, side elevation view of another alternative embodiment of the invention;

FIG. 18 is a partial front elevation view, taken along line 18-18 of FIG. 17; and

15 FIG. 19 is a partially sectional, front elevation view, taken along line 19-19 of FIG. 17.

Description of Preferred Embodiment:

Referring to the drawings, and particularly to FIG. 1 thereof, I show a lower leg prosthesis 10 constructed and assembled in accordance with the teachings of the invention and including a prosthetic pylon 12. For purposes of illustration, the prosthesis 10 is shown as including a prosthetic foot 14 and as having an attachment means 16 at

an upper end thereof for operatively attaching the prosthesis 10 to a wearer, through the use of a socket or other expedient (illustrated, by way of example, as the socket 90, FIGS. 17 and 19).

5 In the preferred embodiment, and as best shown in FIGS. 3 and 4, the pylon 12 includes pylon means having a first portion constituting an upper member 18 and a second portion constituting a lower member 20. As shown in the drawings, these first and second portions are preferably
10 slidingly and reciprocably interengaged with each other in the manner of a sleeve member and an arm member, while retaining their operative horizontal alignment with each other through a relatively close fit between the outside dimensions of the member 18 and the inside dimensions of the
15 lower member 20.

Although the upper and lower members 18 and 20 are illustrated and described as being circular and tubular and coaxially aligned with each other, those skilled in the art will understand that a wide variety of shapes, sizes and
20 alignment patterns may be utilized with efficacy without departing from the scope of the invention. By way of example, but not by way of limitation, the upper and lower members 18 and 20 may have cross-sections which are square (see

FIGS. 11 and 12), rectangular, or D-shaped, or may be solid instead of hollow (see, for example, member 76 of FIG. 15).

Additionally exemplary of the variety of configurations of the pylon members is FIG. 6, discussed below, in which the lower portion 20 may be disposed on the interior of the upper portion 18. In such an embodiment, the respective upper and lower portions must be of sufficient length to otherwise permit the desired unimpeded reciprocation of the prosthesis, as described below.

Moreover, the cylinders 18 and 20 are preferably fabricated from composites of fiber and resin, similar to the prostheses described in my above-listed patents. Such fibers may include, for example, carbon graphite, fiberglass, Kevlar or a similarly strong, light-weight material. The fiber may be in laminated or chopped form. These fibers are preferably retained in the desired operative configuration by polymer impregnation of a thermoplastic or thermosetting resin, such as epoxy, polyester, vinylester, polyethylene or polypropylene. Less expensive materials may be utilized for the pylon members, such as aluminum or extruded nylon, although such materials are heavier.

To enhance the energy storage and release performance of the pylon assembly 12, as more thoroughly described herein, the contiguous surfaces of the cylinders are prefer-

ably coated with teflon, silverstone, a teflon-like fabric, or some similar material to minimize any frictional resistance therebetween.

The pylon 12 further preferably includes energy storage and release means 22. In the preferred embodiment, the energy storage means 22 includes elongated spring elements such as elements 24 and 26, fabricated from the above-described composite materials to provide the necessary energy storage and release, described herein. Those skilled in the art will understand that the invention may be practiced with only one element 24 or 26, or with additional such elements. When a plurality of such elements is utilized, as illustrated in the drawings, they may be assembled in operative relationship with each other through the use of, for example, a nut and bolt combination 28. A protective cap 29 may be provided on the end of the bolt 28.

Examples of alternative embodiments of the elongated spring elements 24 and 26 are shown in FIGS. 7 and 8 as elements 60 and 62. Both the multi-curvilinear spring 60 and the helical spring 62 provide the necessary energy performance, and may be utilized in connection with various other spring elements and energy performance structures such as those illustrated in FIGS. 6, 9 and 10, discussed below.

At least one of the preferred spring elements 24 or 26 is operatively connected to the upper and lower pylon portions 18 and 20, such as through the provision of pivotal attachment means 30 and 32. As best shown in FIG. 5, the 5 attachment means 30 and 32 preferably includes tubular cap members 34 and 36 at the respective upper and lower extremities of the spring element 24. The caps 34 and 36 are slidably received in corresponding respective channels 38 and 40, FIG. 4, and retained there by set screws 42, locking 10 nuts 44 or the like.

The caps 34 and 36, as well as the channels 38 and 40, are preferably coated with teflon, silverstone, or similar material to minimize friction therebetween. Among other things, minimizing the friction between these interfaces and between the contacting surfaces of the upper and lower pylon members 18 and 20 (as described above) reduces the loss of energy due to friction during reciprocation of the pylon. Because of the low amount of friction which must be overcome, the prosthesis 10 can provide cushioning and 15 energy-storage, as more fully described below, for even relatively small compressive loads, with relatively low losses 20 of energy due to friction.

Alternative means for attaching the spring elements 24 and/or 26 to the pylon members 18 and 20 would

include, for example, standard hinges (not shown). An example of one of the other many further alternatives for attachment is illustrated in FIGS. 17-19, discussed herein.

Other purposes of the preferred attachment means 5 30 and 32, in combination with the spring element 24, include the prevention and/or limitation of rotational movement between the respective cylinders 18 and 20. With proper selection of materials and configurations of the cap members 34 and 36 and the spring element 24 (such as size, 10 width, thickness, stiffness and strength of materials), all rotation can be prevented, or some desired and determinable amount of rotation of the lower end of the pylon with respect to the wearer's socket may be permitted. As indicated above, this rotation is similar to that achieved by 15 known prosthetic "rotators". Such rotation is beneficial, and simulates the action of a natural human knee/ankle, in a number of activities that involve the twisting of a person's body with respect to their planted foot, such as golf, tennis, and the like.

20 By way of example, but not by way of limitation, a wider or stiffer spring element 24 would permit less rotation than a relatively narrower and/or "softer" spring element. Such stiffness of the spring element may be determined, for example, by the number of fiber laminates uti-

lized in the fabrication thereof, if the spring element is fabricated of laminates. If the spring is fabricated from other materials, the particular selection and/or treatment process may be utilized to affect the twisting performance, 5 or the upper and lower pylon members 18 and 20 may be "keyed" to each other to prevent or limit twisting.

In the absence of some control or limitation on such twisting of the cylinders 18 and 20 with respect to each other, such twisting could, for example, cause the 10 lower portion of the prosthesis (in the drawings, the prosthetic foot 14) to become misaligned with respect to the wearer's socket.

As indicated above, the spring elements 24 and 26, as well as other components of the present invention, are 15 preferably formed by the incorporation of a plurality of laminae such as the laminae 58, FIG. 2, embedded in a hardened, flexible polymer, similar to the fabrication methods taught in my above-noted prior art patents. Alternative materials include chopped fiber and thermosetting and/or 20 thermoplastic resins. Such fabrication of the spring elements permits the desired energy storage and release characteristics of the spring, achieving a desired balance between sufficient durability to withstand cyclic loading which may be imposed on the spring and flexibility to cushion impacts

of the prosthesis on the ground or other surface and store and release the consequent energy.

The preferred method of manufacturing the spring elements 24 and 26 of the prosthesis 10 is by a thermosetting molding process including the utilization of molds having properly shaped and sized cavities. The cavities are designed to receive the requisite number of laminates and the proper volume of polymer, such that the leg elements 24 and 26 are respectively unitary structures.

As alluded to above, in the preferred embodiment, the lower portion 20 is preferably demountably and adjustably attached to a prosthetic foot 14, although those skilled in the art will understand that the pylon may be utilized in a variety of other manners, such as with a permanently attached or simultaneously- and integrally-formed prosthetic foot member 14 (see, for example, FIGS. 15 and 16 and discussion of same herein). The preferable means for attachment 46 includes a clamp member 48 affixed to the prosthetic foot 14 through the provision of threaded nut and bolt combinations 50, FIGS. 1 and 2, or similar expedient (such as simultaneous formation therewith). In the preferred embodiment, the clamp member 48 may be operably attached at any of a variety of locations along the length of the lower pylon portion 20 by simply positioning the

clamp and tightening the nut and bolt combinations 52. This also permits the adjustment of the "toe-in", "toe-out", fore-and-aft alignment of the foot 14 with respect to the socket (see, by way of example, socket 90, FIGS. 17 and 19).

5 One of the many alternative means for adjusting and attaching the lower leg prosthesis to the lower pylon is illustrated in FIGS. 13 and 14. The foot prosthesis 14 may be operably retained at a selected position along the length of the lower pylon by one or more hose clamps 66.

10 Presently, it appears that high-strength, heavy duty, wide stainless steel clamps should be utilized. The clamps are adjustable by screws assemblies 68 or similar expedient.

15 The strength and consequent performance of the attachment of the foot prosthesis 14 may be improved by the provision of a resin or composite wedge 64, FIGS. 13 and 14, formed on the rearward surface of the foot prosthesis 14. The wedge is shaped to conform to the confronting surface of the pylon, and increases the contact area between the foot 14 and the pylon, adding stability to the attachment.

20 After an amputee has worn the device as illustrated in FIGS. 13 and 14 for some suitable period in order to test the length adjustment and energy performance thereof, the foot 14 may be permanently or semi-permanently

bonded in place through the use of known gluing and/or lamination techniques.

Although cap member 29, FIGS. 3 and 4, is shown as contacting the clamp member 48, those skilled in the art will understand that such contact is not required for the practice of the invention. Indeed, and as set forth below, the imposition of force on the pylon 12 will cause the spring element 24 to flex outwardly, away from the pylon portions 18 and 20, correspondingly moving the cap member 29 away from the portions 18 and 20.

A shroud 54 (shown in phantom in FIG. 1) may be provided for a cosmetic finish. Such a shroud may be installed after the judicious adjustment of the prosthesis by the proper combination of elements 18, 20, 24 and/or 26, as well as foot means 14. The shroud should be designed to accommodate and permit the desired flexure and functioning of the prosthesis, without interfering therewith. A shoe 56 or other appropriate covering may also be worn in connection with the assembled prosthesis.

When external forces are applied to the prosthesis 10, such as during walking, running, etc., the forces cause a relative compression of the length of the pylon means 12. As best shown in FIGS. 3 and 4, the first pylon portion 18 will slide downwardly within the second portion 20. Contem-

poraneously, and as indicated above, the energy storage and release spring elements 24 and 26 will bow outwardly and away from the pylon members 18 and 20.

The amount of compression, and indeed the energy-
5 storage and release characteristics of the prosthetic pylon,
will be determined in large part by the construction and
materials of the element or elements 24 and 26. Prior to
the imposition of such force, the spring elements maintain
the lower member 20 in an extended position relative to the
10 upper member 18. When, for example, a contact-generated
compressive force is impressed upon the lower member, the
lower member 20 will be reciprocated relative to said upper
member 18, to compress said storage means into an energy
storage mode. When the force is released, the energy stor-
15 age means will urge the lower member 20 to its extended
position.

As illustrated in the drawings, the secondary
spring element 26 will not affect the performance of the
prostheses unless and until a sufficiently large compressive
20 force is imposed on the pylon. In such case, the primary
spring element 24 will flex to a sufficient degree to permit
the secondary element 26 to engage the primary element 24,
resulting in a combined resistance to further deflection.

The energy performance of the pylon 12 may be further controlled and/or fine-tuned through the provision of constraining means 70 such as one or more rubber or urethane bands or rings 72, FIG. 6. This band or these bands are 5 preferably dimensioned so that they may be retained about the prosthesis in a position above or below (not shown) the spring element when the prosthesis is in normal use. In this normal position, the band would not affect the energy 10 performance of the prosthesis. In anticipation of heavy impact loading of the prosthesis, however, such as might occur during running or other strenuous exercise, the band 72 may be positioned as illustrated in FIG. 6, so that its elastic resistance to stretching adds to the overall resistance to compression, or "stiffness", of the prosthesis.

FIG. 6 further illustrates an alternative embodiment of the pylon in which an upper pylon member 74 is disposed externally of a lower pylon member 76. In such a configuration, although the foot prosthesis 14 may be selectively positioned along the length of the lower member 76, 20 it must be sufficiently spaced from the upper member 74 to ensure that the desired reciprocation of the pylon members 74 and 76 can occur.

As indicated above, FIGS. 7 and 8 illustrate some of the many alternative embodiments of the elongated spring

elements, indicated as elements 60 and 62. As further indicated above, these elements may be utilized in lieu of and/or in combination to the other spring elements and other energy storage means discussed herein (such as, for example, constraining means 70 of FIG. 6).

FIGS. 9 and 10 illustrate another embodiment of the pylon means 12 of the invention, in which the energy storage means is provided in the form of a resilient, hard rubber rod or inflatable bladder 78. The rod 78 is disposed internally of the lower pylon member 20. The lower end of the upper pylon member 18 is maintained in operative contact with the rod 78 through, for example, the provision of an elastic shock cord 80 or similar expedient. In the embodiment of FIGS. 9 and 10, the shock cord passes through holes 82 and 84 in the lower and upper pylon members, respectively. When compressive loads are imposed on the pylon, the upper member 18 compresses the rubber rod 78; when the load is removed, the rod 78 expands to its original shape and extends the upper member 18 to its original position with respect to the lower member 20.

Another example of the numerous other energy storage means which may be utilized with efficacy in my invention is a plurality of Belville washers (not shown) stacked in an alternating concave/convex manner and disposed inter-

nally of the pylon members, similarly to the rubber rod 78. The number of washers in the stack can be selected and varied to adjust the energy-storage and release performance characteristics of the pylon.

5 FIGS. 11 and 12 illustrate one of the many alternative cross-sections for the upper and lower pylon members. In this embodiment, both the lower member 86 and the upper member 88 incorporate rectangular cross-sections, FIG. 12, which are dimensioned to provide the desired sliding inter-
10 fitment discussed above.

FIGS. 15 and 16 illustrate an alternative embodiment of my invention, in which a prosthetic foot 14 is integrally formed with the lower pylon member 76. Such an embodiment may incorporate, for example, a slightly modified
15 version of the prosthetic leg and foot sold under the trademark FLEX-FOOT®. Appropriate modifications to that leg and foot would include coating the portion 76 (disposed internally of the sleeve member 74) of the leg with teflon, silverstone, or similar low-friction material, and bonding or
20 otherwise attaching the energy-storage means 24 to the foot 14, such as indicated at 75.

FIGS. 17-19 illustrate yet another embodiment of the invention, in which the elongated spring member 92 is operatively connected to the upper pylon member 94 and the

lower pylon member 96 in a manner different from those described above.

With respect to the connection between the upper pylon member 94 and the spring 92, a channel 98 is provided 5 in the top portion of the upper pylon member 94. The channel 98 is slightly wider than the spring 92 and the base of the channel is preferably configured so that the upper end of spring member 92 is adjacent thereto when the spring is in a non-compressed state (such as illustrated in FIGS. 17-10 19). A threaded bolt 100 is operatively mounted (by bonding or similar expedient) in the base of the channel 98 and projects therefrom through a hole 102 in the upper end of spring member 92 and through a hole 104 in the socket member 90. The bolt 100 is preferably threaded only near the outer 15 end of the bolt, in order to engage a nut 106; the remainder of the shaft of the bolt 100 is smooth and may be coated with teflon or similar material in order to minimize friction during compression of the spring, as more thoroughly described below.

20 The connection between the lower pylon member 96 and the spring 92 may preferably be assembled in the following manner. A cap member 108 is threadedly engaged on the lower end of the lower pylon member 96. The cap includes an opening 110 in one side, which is sized to permit the spring

member 92 to flex during compression of the pylon without contacting the sides of the opening 110. Similarly to the base of the channel 98 described above, the end of the lower pylon member 96 is shaped to conform to the non-compressed 5 spring 92 adjacent thereto. In addition, the end of the lower pylon member 96 includes a threaded hole 112, whose purpose is described below.

To assemble the embodiment of FIGS. 17-19, the lower end of the spring 92 is inserted into the opening 110 10 and a hole 114 in the spring 92 is positioned between the threaded hole 112 in the bottom of the pylon member 96 and a hole (not shown) in the cap member 108. In order to permit the spring 92 to be fully inserted, the end 118 of the spring 92 is preferably shaped to conform to the confronting 15 annular wall of the cap member 108. A threaded bolt 116 is then inserted through the hole (not shown) in the cap member 108, through the hole 114 in the lower end of the spring element 92, and then threadedly engaged with the hole 112 in the bottom of the pylon member 96. As with the upper bolt 100, the bolt 116 is preferably threaded only on the portion 20 of the bolt that engages the threaded hole 112. The remainder of the bolt 116 is preferably smooth and may be coated with teflon or similar material in order to minimize friction during compression of the spring, as described below.

The attachment configuration of FIGS. 17-19 provides numerous advantages. For example, the spring element 92 can be configured with a longer and smoother curvature than that permitted in, for example, the embodiment of FIG. 5. In addition, as the pylon and the spring element 92 are compressed during use, the ends of the spring element 92 will correspondingly move away, respectively, from the curved base of the channel 98 and the curved bottom of the lower pylon member 96, and will move into contact with, 10 respectively, the bottom 120 of the socket 90 and the interior surface 122 of the cap member 108. The area of this contact increases as the compression of the spring 92 increases, and causes an effective shortening of the lever arm by which force is transmitted to the spring. In effect, 15 the spring 92 becomes "stiffer" (exerts a greater resistance to flexure) in proportion to the amount of force exerted thereon. As those skilled in the art will understand, this permits an extremely desirable energy performance, in that the initial loading of the pylon is readily stored by the 20 spring 92, but extreme loading will meet with more "stiffness".

The holes 102 and 114 are preferably sufficiently sized and configured (and may be teflon-coated as well) so that, during the compression of the pylon and consequent

flexure of the pylon spring element 92, any contact between the holes and their respective bolts 100 and 116 results in minimal frictional energy loss.

By the prosthesis of my invention I provide a leg
5 prosthesis pylon which can be carefully matched to the weight, stride and physical characteristics of the wearer. This is accomplished by carefully selecting and balancing the respective physical characteristics of the energy storage means 22 and the other portions of the pylon.

10 Moreover, the various components and portions of the present invention may be provided in a variety of sizes, thicknesses, and materials which may be interchangeable with correspondingly-shaped components to permit fine-tuning of the prosthesis to the needs of the wearer thereof. The
15 pylon of my invention may also be used in combination with numerous prior art prosthetic devices to improve the performance of such prior art devices.

The prosthesis of my invention has been described with some particularity but the specific designs and constructions disclosed are not to be taken as delimiting of the invention in that various obvious modifications will at once make themselves apparent to those of ordinary skill in the art, all of which will not depart from the essence of

the invention and all such changes and modifications are intended to be encompassed within the appended claims.

Claims:

I CLAIM:

5

1. In a leg prosthesis having an upper end attachable to a wearer and a lower end for contacting a supporting surface, the combination of: pylon means, said pylon means having first and second portions operatively retained in reciprocable alignment with each another; and energy storage and release means operatively associated with said first and second portions, whereby the imposition of force on the prosthesis and subsequent release of energy therefrom will cause corresponding energy storage and release in said energy storage and release means and contemporaneous reciprocation of said first and second portions with respect to each another.

2. The leg prosthesis of Claim 1 in which said energy storage and release means includes one or more elongated spring elements.

3. The leg prosthesis of Claim 2 in which opposite ends of said one or more elongated spring elements are connected to said first and second portions.

5 4. The leg prosthesis of Claim 2 further including constraining means for constraining the amount of deflection of said one or more elongated spring elements.

10 5. The leg prosthesis of Claim 1 in which said first and second portions of said pylon means include an interfitting sleeve member and arm member.

15 6. The leg prosthesis of Claim 5 in which said energy storage and release means includes one or more elongated spring elements.

7. The leg prosthesis of Claim 6 in which opposite ends of said one or more elongated spring elements are operatively connected to said first and second portions.

20

8. The leg prosthesis of Claim 6 further including constraining means for constraining the amount of deflection of said one or more elongated spring elements.

9. The leg prosthesis of Claim 1 or Claim 2 or Claim 3 or Claim 4 or Claim 5 or Claim 6 or Claim 7 or Claim 8 in which said energy storage and release means is partially or completely fabricated from a thermosetting resin.

5

10. The leg prosthesis of Claim 1 or Claim 2 or Claim 3 or Claim 4 or Claim 5 or Claim 6 or Claim 7 or Claim 8 in which said energy storage and release means is partially or completely fabricated from a thermoplastic resin.

10

11. The leg prosthesis of Claim 1 or Claim 2 or Claim 3 or Claim 4 or Claim 5 or Claim 6 or Claim 7 or Claim 8 in which said energy storage and release means is partially fabricated from chopped fiber.

15

12. The leg prosthesis of Claim 1 or Claim 2 or Claim 3 or Claim 4 or Claim 5 or Claim 6 or Claim 7 or Claim 8 in which said energy storage and release means is partially or completely fabricated from superimposed laminates.

20

13. The leg prosthesis of Claim 1 or Claim 2 or Claim 3 or Claim 4 or Claim 5 or Claim 6 or Claim 7 or Claim 8 in which said energy storage and release means includes one or more non-elongated spring members.

14. The leg prosthesis of Claim 1 or Claim 2 or
Claim 3 or Claim 4 or Claim 5 or Claim 6 or Claim 7 or Claim
8 including adjustment means for determining the distance
5 between said upper end and said lower end of said prosthesis
prior to the imposition of force on said prosthesis.

15. In a prosthetic pylon, the combination of:
upper securement means for securing said pylon to a wearer;
10 lower attachment means for attaching said pylon to a pros-
thetic foot or other lower leg prosthesis; a first pylon
portion operatively connected to said upper securement
means; a second pylon portion operatively connected to said
lower attachment means; and energy storage and release means
15 operably engaging said first and second pylon portions
whereby the imposition of loads on the lower leg prosthesis
causes relative movement between said first and second pylon
portions and the consequent storage of energy in said energy
storage and release means.

20

16. The prosthetic pylon of Claim 15 in which
said energy storage and release means includes one or more
elongated spring elements.

17. The prosthetic pylon of Claim 16 in which opposite ends of said one or more elongated spring elements are connected to said first and second portions, respectively.

5

18. The leg prosthesis of Claim 16 further including constraining means for constraining the amount of deflection of said one or more elongated spring elements.

10

19. The prosthetic pylon of Claim 15 in which said first and second pylon portions are slidably interengaged with each another.

15 20. The prosthetic pylon of Claim 19 in which said energy storage and release means includes one or more elongated spring elements.

20 21. The prosthetic pylon of Claim 20 in which opposite ends of said one or more elongated spring elements are connected to said first and second portions.

22. The leg prosthesis of Claim 20 further including constraining means for constraining the amount of deflection of said one or more elongated spring elements.

23. The prosthetic pylon of Claim 15 or Claim 16
or Claim 17 or Claim 18 or Claim 19 or Claim 20 or Claim 21
or Claim 22 in which said energy storage and release means
5 is partially or completely fabricated from a thermosetting
resin.

24. The prosthetic pylon of Claim 15 or Claim 16
or Claim 17 or Claim 18 or Claim 19 or Claim 20 or Claim 21
10 or Claim 22 in which said energy storage and release means
is partially or completely fabricated from a thermoplastic
resin.

25. The prosthetic pylon of Claim 15 or Claim 16
15 or Claim 17 or Claim 18 or Claim 19 or Claim 20 or Claim 21
or Claim 22 in which said energy storage and release means
is partially fabricated from chopped fiber.

26. The prosthetic pylon of Claim 15 or Claim 16
20 or Claim 17 or Claim 18 or Claim 19 or Claim 20 or Claim 21
or Claim 22 in which said energy storage and release means
is partially or completely fabricated from superimposed lam-
inates.

27. The prosthetic pylon of Claim 15 or Claim 16 or Claim 17 or Claim 18 or Claim 19 or Claim 20 or Claim 21 or Claim 22 in which said energy storage and release means includes one or more non-elongated spring members.

5

28. The prosthetic pylon of Claim 15 or Claim 16 or Claim 17 or Claim 18 or Claim 19 or Claim 20 or Claim 21 or Claim 22 in which said lower attachment means for attaching said pylon to a prosthetic foot or other lower leg prosthesis permits selectable determination of the location of such attachment.

15 29. In a prosthetic leg device, the combination of: an upper pylon member adapted for securement to a wearer's stump; a lower pylon member reciprocatingly inter-fitted with said upper pylon member; and energy storage and release means operatively engaging said upper pylon member and said lower pylon member.

20 30. The prosthetic leg device of Claim 29 in which said first and second pylon members have tubular configurations.

31. The prosthetic leg device of Claim 29 in which said energy storage and release means includes one or more elongated spring elements.

5 32. The prosthetic leg device of Claim 31 in which said first and second pylon members have tubular configurations.

10 33. The prosthetic leg device of Claim 31 further including constraining means for constraining the amount of deflection of said one or more elongated spring elements.

15 34. The prosthetic leg device of Claim 29 or Claim 30 or Claim 31 or Claim 32 or Claim 33 in which said energy storage and release means is partially or completely fabricated from a thermosetting resin.

20 35. The prosthetic leg device of Claim 29 or Claim 30 or Claim 31 or Claim 32 or Claim 33 in which said energy storage and release means is partially or completely fabricated from a thermoplastic resin.

36. The prosthetic leg device of Claim 29 or Claim 30 or Claim 31 or Claim 32 or Claim 33 in which said

energy storage and release means is partially fabricated from chopped fiber.

37. The prosthetic leg device of Claim 29 or
5 Claim 30 or Claim 31 or Claim 32 or Claim 33 in which said energy storage and release means is partially or completely fabricated from superimposed laminates.

38. The prosthetic leg device of Claim 29 or
10 Claim 30 or Claim 31 or Claim 32 or Claim 33 in which said energy storage and release means includes one or more non-elongated spring members.

39. In a prosthetic leg pylon, the combination
15 of: upper and lower interengagable, relatively reciprocatable pylon members; and energy storage means connected or disposed between said upper and lower pylon members to maintain said lower member in an extended position relative to said upper member, whereby when a contact-generated compressive force is impressed upon said lower member, said lower member will be reciprocated relatively to said upper member to compress said storage means into an energy storage mode, and when said force is released said storage means will urge said lower member to its extended position.

40. The prosthetic leg pylon of Claim 39, said upper pylon member having amputee-engaging means operatively associated therewith and said lower pylon member having 5 surface-engaging means operatively associated therewith.

41. The prosthetic leg pylon of Claim 40, in which said operatively association of said surface-engaging means and said lower pylon member is a selectively positionable association. 10

42. The prosthetic leg pylon of Claim 39, in which said energy storage means includes one or more non-elongated spring members.

15

43. The prosthetic leg pylon of Claim 39 or Claim 40 or Claim 41 or Claim 42 in which said energy storage means includes one or more elongated spring elements.

20

44. The prosthetic leg pylon of Claim 43 in which opposite ends of said one or more elongated spring elements are operatively connected to said upper and lower pylon members.

45. The prosthetic leg device of Claim 43 further including constraining means for constraining the amount of deflection of said one or more elongated spring elements.

5 46. The prosthetic leg pylon of Claim 43 in which said upper and lower pylon members include an interfitting sleeve member and arm member.

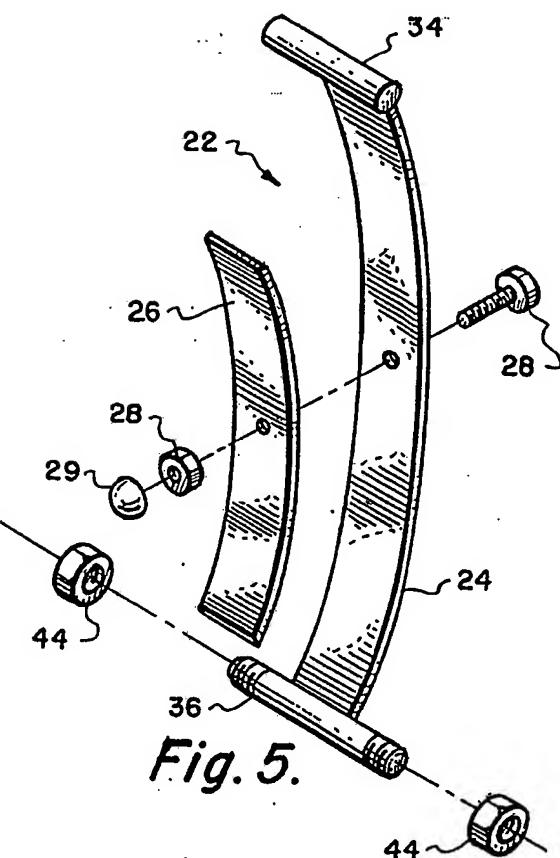
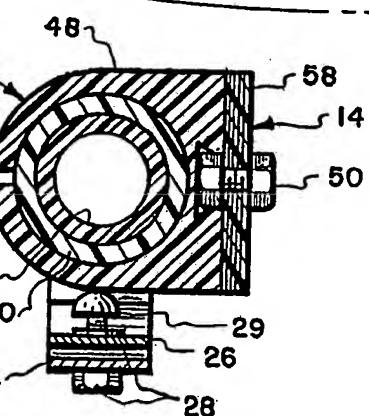
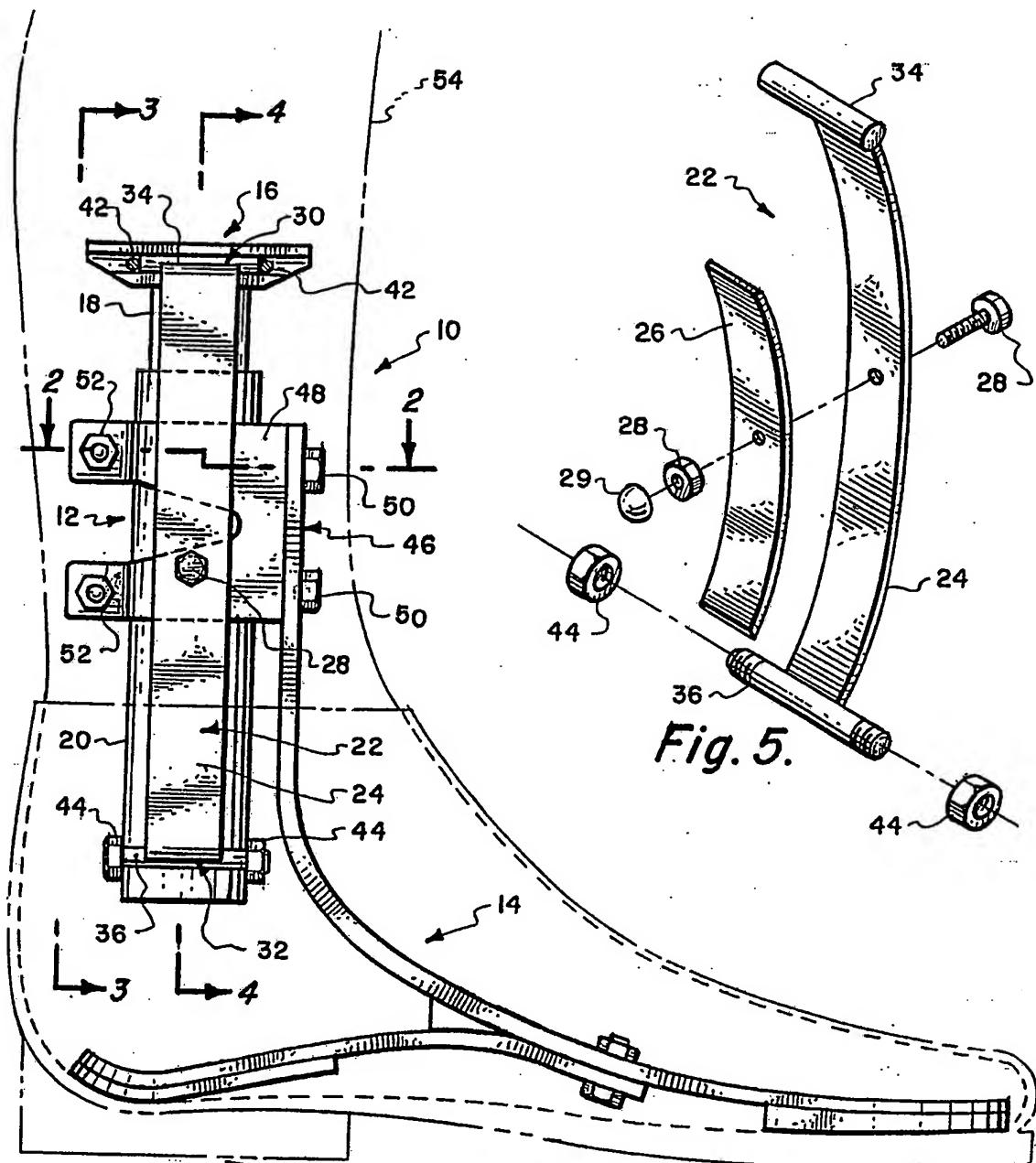
10 47. The prosthetic leg pylon of Claim 43 in which said energy storage means is partially or completely fabricated from a thermosetting resin.

15 48. The prosthetic leg pylon of Claim 43 in which said energy storage means is partially or completely fabricated from a thermoplastic resin.

49. The prosthetic leg pylon of Claim 43 in which said energy storage means is partially fabricated from chopped fiber.

20

50. The prosthetic leg pylon of Claim 43 in which said energy storage means is partially or completely fabricated from superimposed laminates.



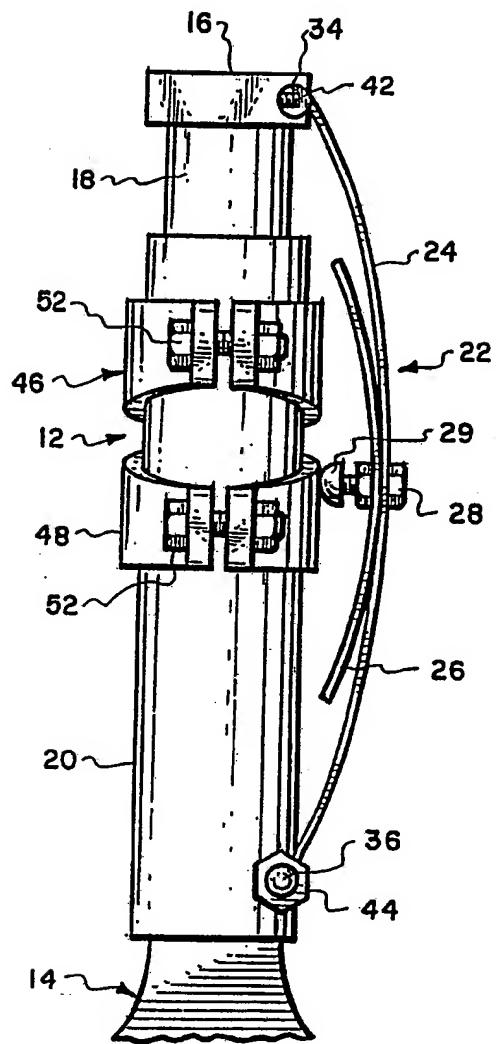


Fig. 3.

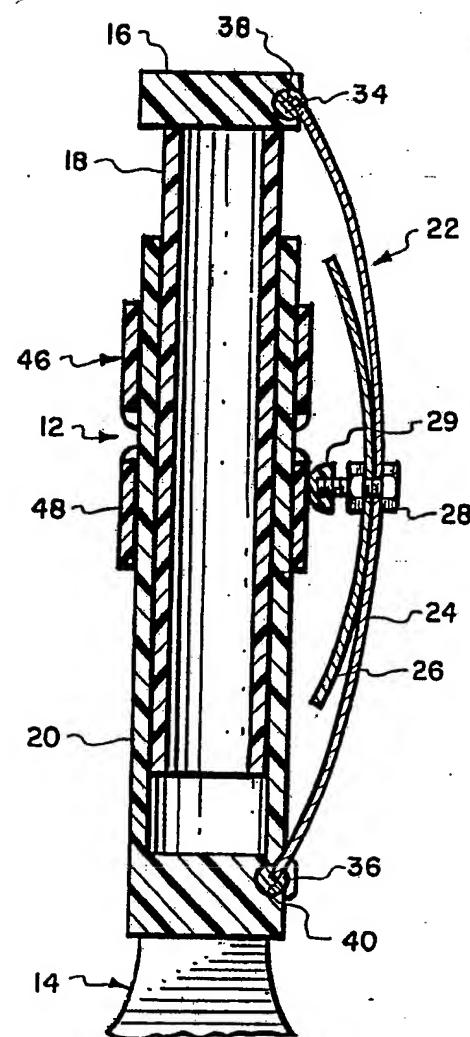
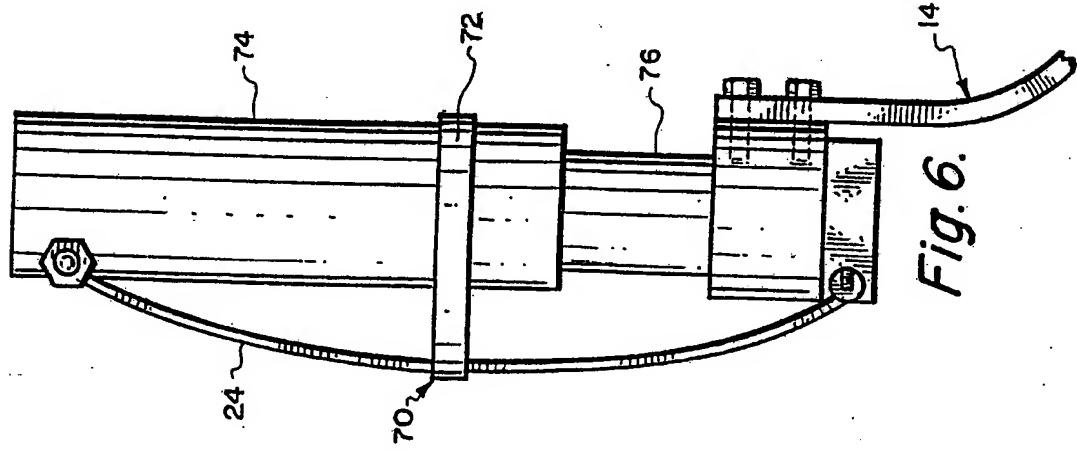
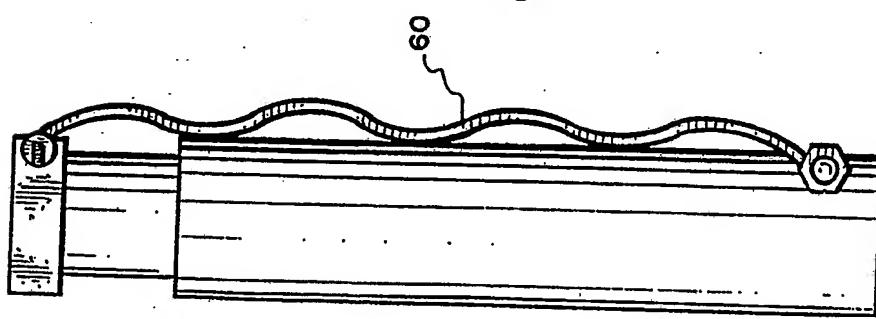
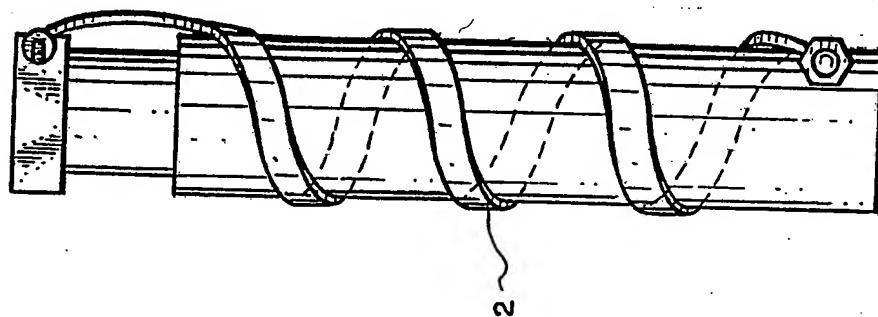
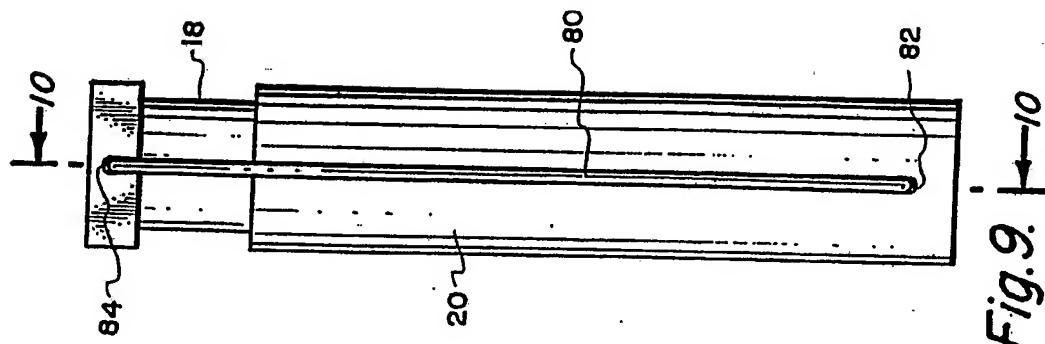
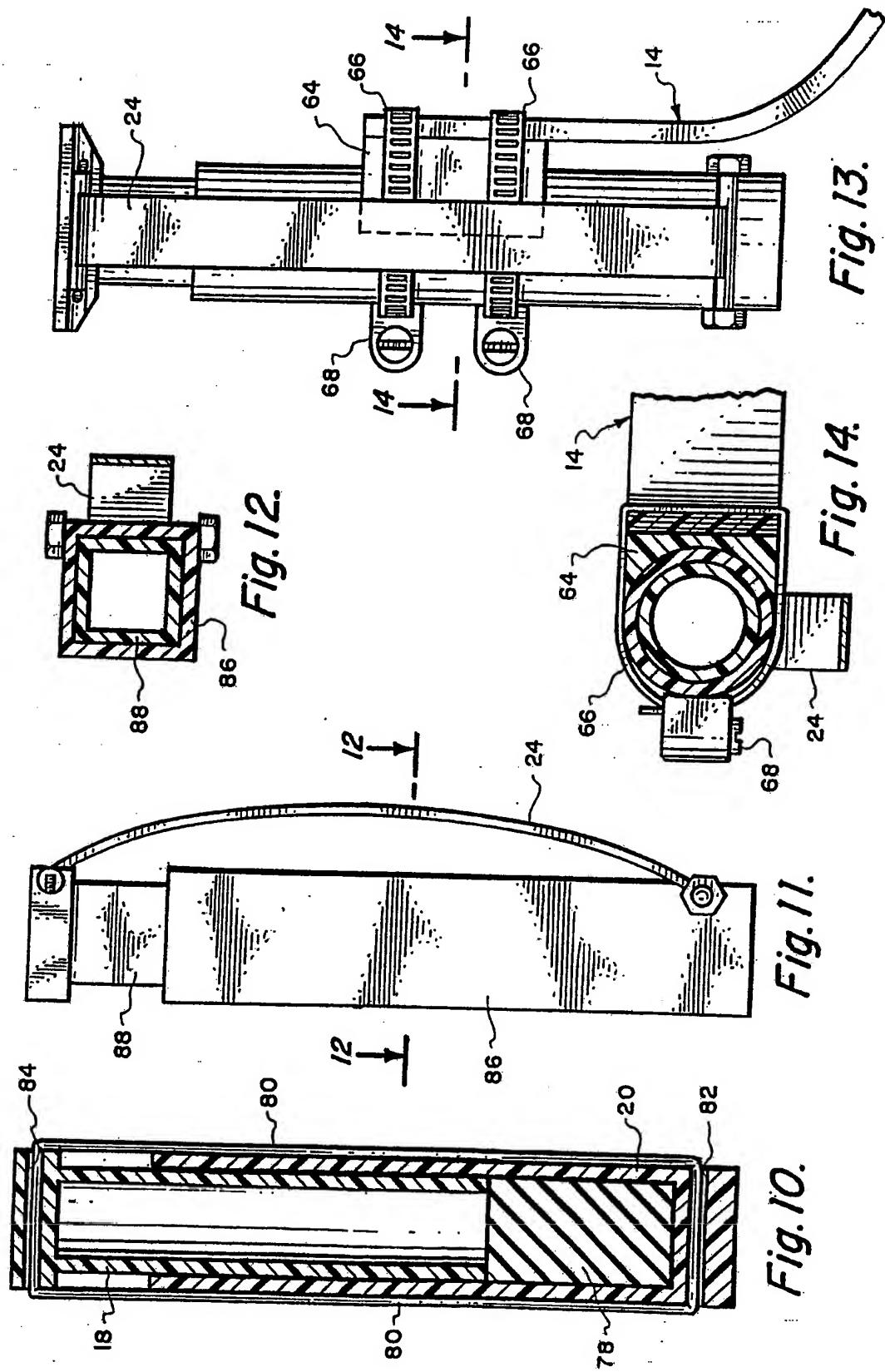


Fig. 4.





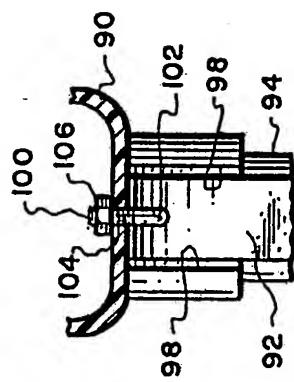


Fig. 19.

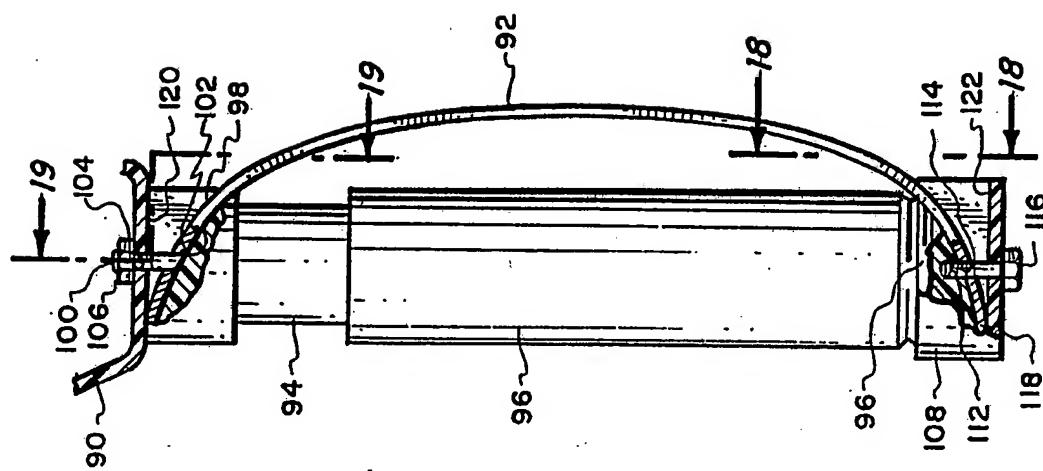


Fig. 17.

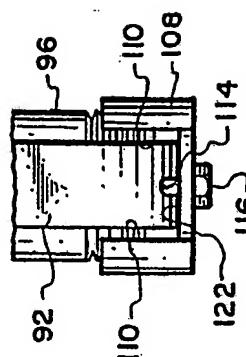


Fig. 18.

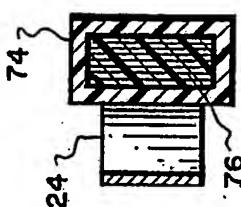


Fig. 16.

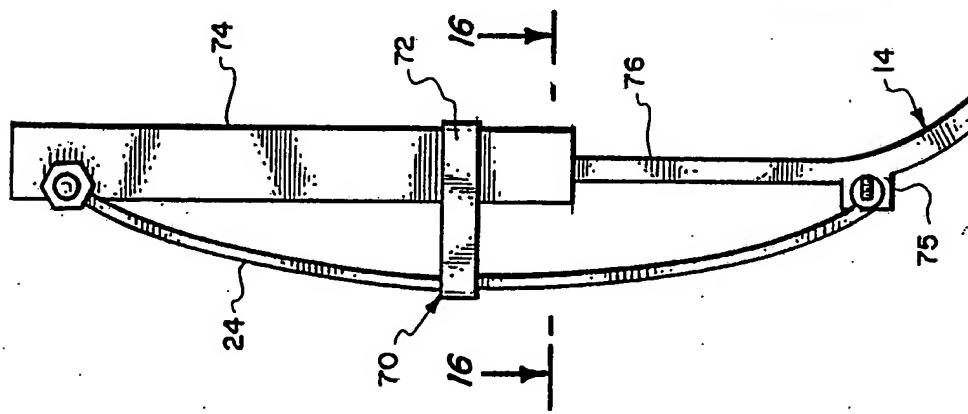


Fig. 15.

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 92/08308

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)⁶

According to International Patent Classification (IPC) or to both National Classification and IPC
 Int.Cl. 5 A61F2/78

II. FIELDS SEARCHED

Minimum Documentation Searched⁷

Classification System	Classification Symbols
Int.Cl. 5	A61F

Documentation Searched other than Minimum Documentation
 to the Extent that such Documents are Included in the Fields Searched⁸

III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹

Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
X	US,A,2 699 554 (COMELLI) 7 July 1953	1,5, 13-15, 19,27, 29,30, 38-40,42
Y	see column 1, line 62 - column 2, line 7; figure 1	4,8,16, 18,20, 31-33, 41,43, 45,46
A	---	
X	BE,A,428 287 (GASPARD) 23 May 1938 see the whole document	1,5,39
Y	---	2
A	---	3,6,7,21
		-/-

¹⁰ Special categories of cited documents¹⁰^{"A"} document defining the general state of the art which is not considered to be of particular relevance^{"E"} earlier document but published on or after the international filing date^{"L"} document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)^{"O"} document referring to an oral disclosure, use, exhibition or other means^{"P"} document published prior to the international filing date but later than the priority date claimed^{"T"} later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention^{"X"} document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step^{"Y"} document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.^{"&"} document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search

01 FEBRUARY 1993

Date of Mailing of this International Search Report

10.02.93

International Searching Authority

EUROPEAN PATENT OFFICE

Signature of Authorized Officer

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category ^a	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
Y	US,A,2 570 735 (WEISE) 18 March 1949 see column 2, line 24; figures 1-3 ---	2, 4, 8, 16, 18, 20, 31-33, 43, 45, 46
Y	DE,C,328 107 (LOWITZSCH) 5 February 1919 see figures 1,2 ---	41
A	GB,A,2 085 351 (CHAS. A. BLATCHFORD SONS LIMITED) 28 April 1982 see page 1, line 49 see page 1, line 71 - line 72 see page 2, line 42 - line 44 ---	1, 29 9-11, 23-25, 34-36, 47-49
A	US,A,5 037 444 (PHILLIPS) 6 August 1991 cited in the application see column 2, line 15 ---	12, 26, 37, 50
A	FR,A,2 501 999 (GOUDOU) 24 September 1982 see figure 3 -----	1, 3, 17, 21, 44, 46

ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.

US 9208308
SA 65814

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information. 01/02/93

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A-2699554		None		
BE-A-428287		FR-A-	838443	
		US-A-	2189928	
US-A-2570735		None		
DE-C-328107		None		
GB-A-2085351	28-04-82	SE-B-	445515	30-06-86
		DE-A-	3137652	15-07-82
		FR-A-	2490951	02-04-82
		SE-A-	8106035	13-04-83
		US-A-	4397048	09-08-83
US-A-5037444	06-08-91	None		
FR-A-2501999	24-09-82	None		